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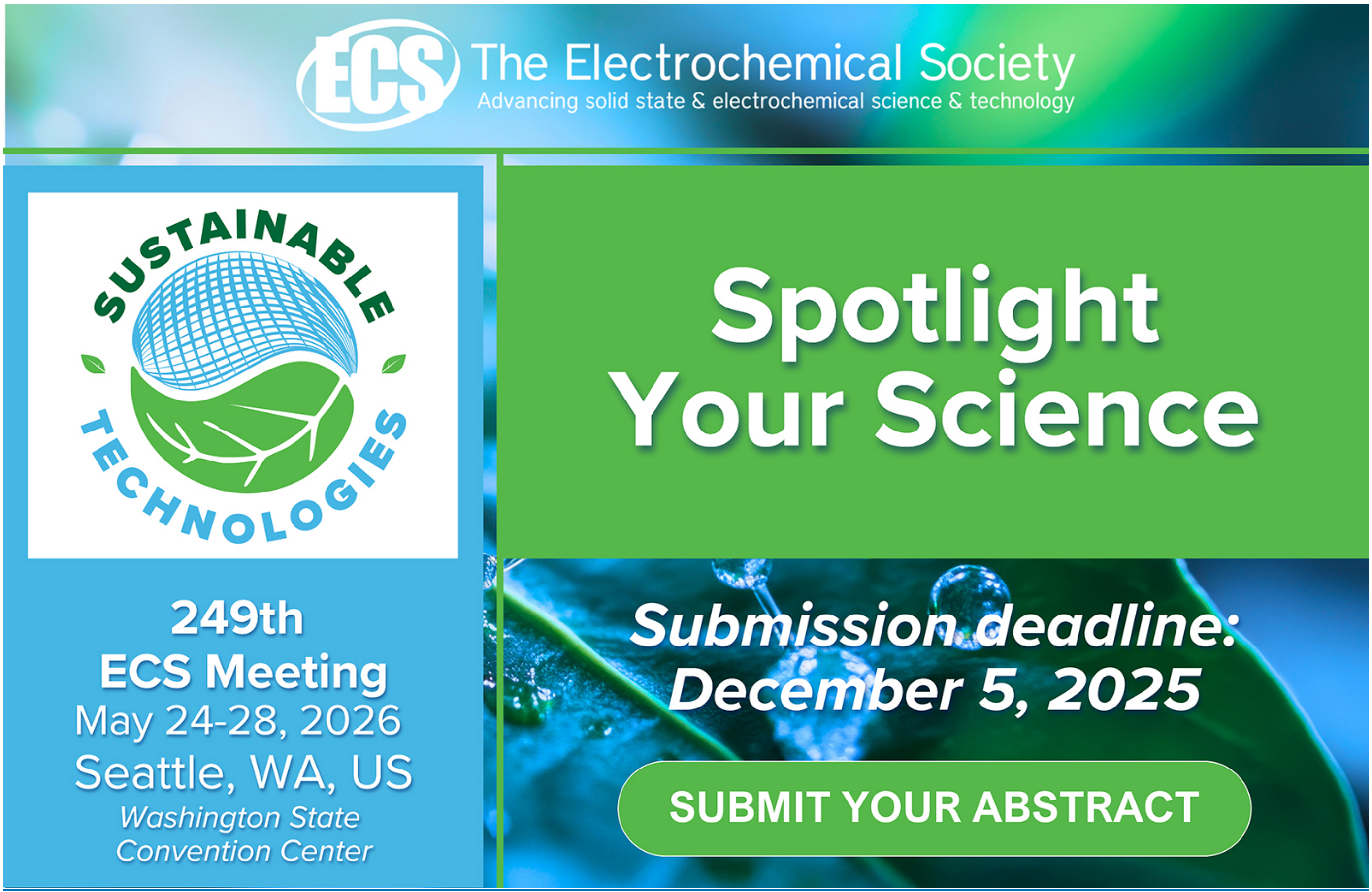

Determining the predictive reliability of the water meters using the failure rate estimation. Case study - single jet cold water meter

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Abstract. The paper presents a method of estimating the failure rate by applying the extrapolation method, for the case of a single jet cold water meter. The predictive reliability of a system (water meter) is the reliability expressed by the reliability indicators resulting from forecast calculations based on the reliability of the component elements. In order to analyze the reliability of the considered water meter, it is divided into component elements or blocks of elements, which are functional or constructive units, whose reliability indicators are determined in operation. The water meter must be seen as a complex product, the structure of which includes a number of elements forming a system comprising a series of elements connected in one whole, that fulfills a specific technical function. The logical connection of the elements and the component blocks gives the logical reliability scheme with the subsystems and structural elements of the pressure measuring means. Finally, the logic mechanical reliability scheme of the water meter is determined, this being analyzed as a functional complex system, expressing the link between the reliability of the component elements and the reliability of the system as a whole.

1. Introduction

At present, considerable interest is granted to the conservation of the quality of the environment, the rational utilization of all natural resources, including water resources, identification and understanding of the causes of deterioration in the quality of the natural environment structure and components in order to prevent irrational use, waste of the resources. In the category of rational use of natural resources, which has been and still is a major concern, both nationally and internationally, fall the water and especially drinking water. Concerns for the rational use, thus eliminating the losses of drinking water, are priority objectives.

Since the quality of any process depends on the value of the measurement information and due to the necessity of a higher and higher precision, at present, there is an increasing interest in metrological reliability [1-5].

2. Case study - single jet cold water meter

Depending on the structural scheme of a water meter (figure 1), one can construct the functional block diagram of the mechanical means of measuring volumes [6].

The reliability of a water meter (mechanical device for measuring volumes) cannot be treated as the reliability of a product, which consists of an element [7]. A water meter must be regarded as a complex structure which includes a number of elements forming a system comprising a set of elements connected in a whole, which performs a specific function technique. These elements included in the composition of a water meter form: sub input unit - water meter body, unit of measurement - rotor (turbine), transmission unit (magnetic coupling), and integration and indicating subassembly - mechanical integrator.

A water meter consists of [6]:

- brass meter body provided with inlet channels for admission/exhaust of water. The exhaust channel is provided with a filter;
- turbine - measuring device operating under water pressure;
- magnetic coupling, which ensures the transmission of motion from the measurement unit to the integration unit;
- Integrating unit consisting of eight cylindrical drums and a dial with pointer and a graduated scale with division value of 0.05 dm^3. The mechanism is equipped with a device for removing condensation from the rolls.

The fluid flow through the meter produces the movement of the rotor, whose speed is proportional to the circulating water flow through the device. Rotational motion is demultiplicated and transmitted to the integration and indicating units. The transmission of motion is achieved by magnetic coupling since the mechanism is of a dry type.

In case of a single jet water meter, the body is made in such a way that the water jet hits the turbine tangentially, in a single point.

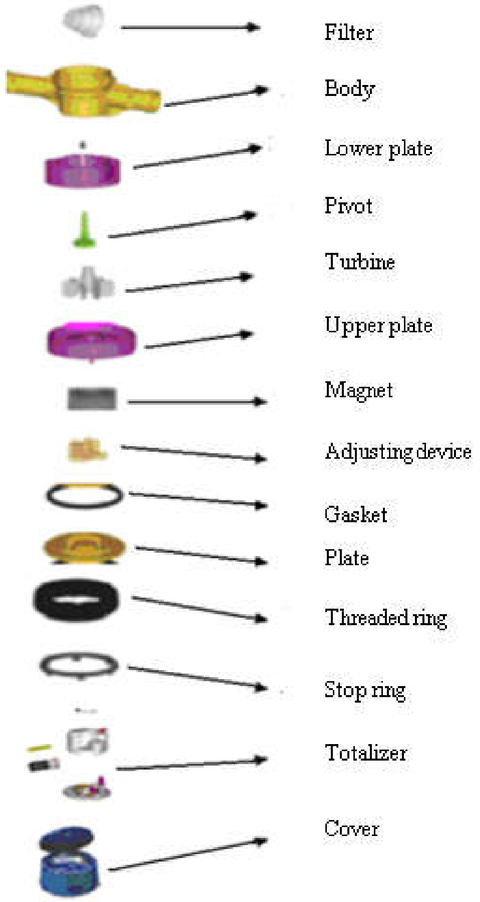

Figure 1. The single jet cold water meter – components.

3. Logical scheme of reliability for a cold single jet water meter

In order to analyze the reliability of the systems, they are divided into component elements or blocks of elements, which are functional or constructive units, whose reliability indicators are determined in exploitation. This decomposition is not unique, depending on how the system reliability is analyzed, the information that is available about the system components or their reliability parameters. By logically connecting the components and blocks, the logical reliability scheme with the subsystems and structural elements of the pressure measurement means is obtained [6].

Finally, the logical mechanical reliability scheme of the pressure measuring instrument is determined, analyzed as a functional complex system, expressing the link between the reliability of the component elements and the reliability of the system as a whole.

The logical scheme of reliability of a mechanically metered volume measurement means, which is representatively adopted, is shown in figure 2, and the integration and indicating subassembly unit, which is part of this scheme, is shown in figure 3.

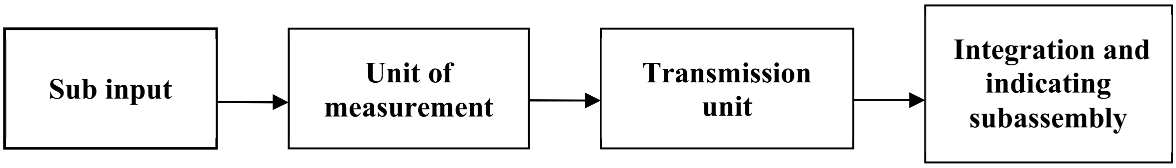

Figure 2. Logical scheme of reliability of a single jet cold water meter.

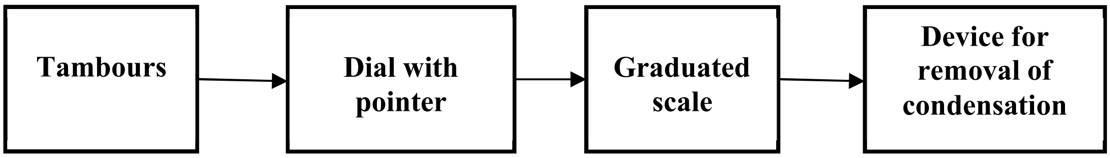

Figure 3. Integration and indicating subassembly unit for a single jet cold water meter.

4. Estimation of failure rate by the extrapolation method

In the logical scheme of reliability of the chosen model (figure 2), the following issues are taken into account: each element of the system has a random operating time and can be found in two states: operating or non-operating; serially related items have only one way of communicating. The block, module, or subsystem is a group of elements within the system, typically having the same connection mode that works correctly if it correctly transfers the input-to-output information [6].

The components of the system can be characterized by the probability of operation R(t) or the probability of failure Fi(t) = 1 - R(t). The system is characterized, in its turn, by the probability of operation R(t) or the probability of malfunction Fs(t) = 1 - R(t). The unequivocal structural conveys the relationship between R(t), or Fs(t) and Ri(t) or Fi(t). Finding the analytical expression of this relation, the mathematical model or numerical values of Rs (t) or Fs (t) for given Ri (t) or Fi (t), represent the fundamental problem of the system reliability [7-9]. In conclusion, the purpose of the structural reliability analysis is to determine the functional relationship between the reliability function R(t) of the system and the reliability functions Ri of the component elements:

$$R_s = \psi (R_1, R_2, \ldots, R_n) \qquad (1)$$

The logical model introduces essential simplifications to the functional model, where the analysis is based on knowing the probability densities associated with component parameters.

The first simplification introduced in the logical model is that the reliability functions Ri that characterize the system components are assumed to be known according to the actual failure criteria imposed by the component parameter system; thus, the logic-based analysis does not require a prior calculation of the individual reliability functions, starting from the probability densities of the parameters.

The second simplification is that the structure of the system is described by the Boolean function (1), which is not particularly complex.

$$R_s(t) = \prod_{i=1}^{n} R_i(t) \tag{2}$$

Since the probability Rs(t) is the product of exponential functions (2), its expression will also be an exponential function:

$$R_s(t) = \prod_{i=1}^{n} e^{-\lambda_i t} = e^{-\sum_{i=1}^{n} \lambda_i t} = e^{-\lambda_s t} \tag{3}$$

where:

$$\lambda_s = \sum_{i=1}^{n} \lambda_i \tag{4}$$

The reliability of a system is noticed to be lower as its complexity is greater.

In order to estimate the system failure rate λ_s of a representatively adopted water meter (figure 1), whose logic scheme is shown in figure 2, based on the data from the literature, one can consider table 1, which contains the values of the fault intensities λ_i of the component elements of the analyzed water meter.

Table 1. Values of failure intensity for component parts of water meters [7, 9].

Current number	Element name	Values of exponential distribution parameters E(x; λ) $\lambda \cdot 10^{-6}$/h		
		Minimum value	Medium value	Maximum value
1.	Filter	0.045	0.3	0.8
2.	Body	0.0005	0.0125	0.041
3.	Lower plate	0.015	0.145	0.175
4.	Pivot	0.08	0.2	0.35
5.	Turbine	0.5	0.68	1.039
6.	Upper plate	0.015	0.175	0.700
7.	Magnet	0.24	0.600	0.930
8.	Adjusting device	0.7	2.14	5.54
9.	Gasket	0.01	0.02	0.03
10.	Plate	0.02	0.5	1
11.	Threaded ring	0.250	0.700	1.120
12.	Stop ring	0.01	0.02	0.03
13.	Totalizer	0.011	0.02	1.96
14.	Cover	0.002	0.006	0.01

Thus, based on the numerical values in table 1, using the relation (4), the value of the failure intensity of the analyzed system is determined as follows [7, 8]:

$$\lambda_s = \sum_{i=1}^{9} \lambda_i = \lambda_1 + \lambda_2 + ... + \lambda_{14} = 3.834 \cdot 10^{-6} \tag{5}$$

The times to failure for the components of a water meter have exponential distributions [6, 9].

5. Conclusions

The paper presents a method for determining the predictive reliability of a single jet cold water meter using the failure rate estimation.

The analysis of the predictive reliability represents a basic tool in product design, in order to predict their performance in terms of reliability and to optimize the constructive design of the product in order to ensure a certain level of reliability. The importance of the predictive design reliability analysis is argued by the fact that the reliability of the products is determined by 40-80% of the quality of the project. Predictive reliability indicators provide only an indicative value for the performance of the product. The calculation of predictive reliability is made by taking into account the specificity and particularities of each system or each concrete use. For this it is necessary to know the relationships between the system parameters and the parameters of the elements.

The predictive reliability analysis addresses the maturity period of the product in which the defects are random, at a relatively constant and stable rate. This is the reason why most of the predictive reliability analyzes are based on the statistical model of the exponential distribution. The predictive analysis is based on previous experience on the testing or operation of identical or similar components under identical or similar conditions to the equipment under consideration.

The operational reliability of the product is generally lower than the predictive or experimental reliability. An important cause of the differences between predictive and operational reliability is given by the conditions of use of that product. This is why, in calculating predictive reliability, these factors have to be taken into account by means of environmental coefficients.

As further work, it is intended to apply this study for different types of water meters and to compare the results obtained.

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